DRIVE AXLE ASSEMBLY FOR HYBRID ELECTRIC VEHICLE

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ABSTRACT
An axle assembly mounts an electric motor to a central housing opposite an input yoke that is driven by an engine. The input yoke is mounted along an axis parallel to the electric motor to alternatively or additionally permit the engine to drive a gear reduction within the axle housing through a planetary gear assembly. Another axle assembly is powered by just an electric motor to provide a relatively lighter duty axle assembly for yet another vehicle configuration.

24 Claims, 4 Drawing Sheets
DRIVE AXLE ASSEMBLY FOR HYBRID ELECTRIC VEHICLE

BACKGROUND OF THE INVENTION

The present invention relates to a drive axle assembly including an electric motor, and more particularly to an axle configuration that locates the electric motor in an axle housing opposite from an engine input. There is an increasing demand for hybrid electric driven and hybrid electric assisted vehicles. Electric motors for such applications are typically sized to meet both torque and speed requirements, which may not be the most effective for the operational requirements of such vehicles. Relatively large electric motors are often utilized to meet the torque requirements. This may result in an oversized motor for most operational conditions. Moreover, the relatively large electric motors may be difficult to package in certain vehicle configurations. Conversely, utilizing a multiple of relatively smaller electric motors may increase complexity. Electric hybrid power trains offer advantages for both torque and speed requirements. However, vehicle manufacturers may be reluctant to adapt electric hybrid power trains to existing vehicles due to the expense associated with redesign. Such redesign often requires relatively expensive and complicated chassis modifications to mount the additional electric components such as motors and gearboxes.

Accordingly, it is desirable to provide a lightweight and compact electric motor driven axle configuration, which provides an electric hybrid power train that utilizes relatively conventional axle and suspension components to minimize redesign of existing vehicle structure.

SUMMARY OF THE INVENTION

The axle assembly according to the present invention mounts an electric motor directly to a drive axle assembly. The electric motor is mounted to an axle housing opposite an input yoke, which is driven by an engine. The input yoke is mounted along an axis parallel to the electric motor to alternatively (or additionally) permit the engine to drive a gear reduction and differential gear box located within the axle housing.

The electric motor and the engine drive the gear reduction through a planetary gear assembly. The planetary gear assembly reduces the speed from an electric motor shaft to a pinion gear within the gear reduction. The input yoke drives an input shaft which is directly engaged with a planet carrier of the planetary gear assembly such that the input shaft directly drives the pinion gear without speed reduction. That is, in a disclosed embodiment there is no reduction between the input yoke and pinion gear.

In another embodiment, an axle assembly is powered only by the electric motor to provide a relatively lighter duty axle assembly for a vehicle configuration that does not require significant modification to the axle assembly.

The present invention therefore provides a lightweight and compact electric motor driven axle configuration, which permits electric hybrid power train configurations that utilize relatively conventional axle and suspension components to minimize redesign of the vehicle structure.

BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the currently preferred embodiment. The drawings that accompany the detailed description can be briefly described as follows:

FIG. 1 is a general perspective view of an exemplary vehicle embodiment for use with the present invention;

FIG. 2 is a perspective partial sectional view of an axle assembly of the present invention;

FIG. 3 is a sectional side view of an axle assembly of the present invention taken along line 3—3 in FIG. 2;

FIG. 4 is an expanded sectional view of a planetary gear assembly which receives input from both an electric motor and an engine; and

FIG. 5 is a sectional side view of another axle assembly.
should be understood that various bearing and seal locations are included within the gearbox. One of ordinary skill in the art, with the benefit of this disclosure, would know various ways to mount motor shaft 38.

The motor shaft 38 drives a pinion gear 44 that drives a ring gear 46 through an input gearbox 50 (also illustrated in FIG. 4). The input gearbox 50 also receives power from the engine 28 through the input yoke 34. That is, the input gearbox 50 operates as a transmission to drive input from both the engine 28 and the electric motor 24.

The motor shaft 38 is preferably vertically offset from axis D (see FIG. 3). The ring gear 46 drives the first axle shaft 36a and the second axle shaft 36b through the gearbox 32 such as a differential or the like (also illustrated in FIG. 2). The gearbox 32 may additionally include a speed reduction gearbox to provide a relatively lightweight and compact axle assembly. It should be understood that one of ordinary skill, with the benefit of this disclosure, will understand the design of various gear trains which could be utilized to transfer power from the ring gear 46 to the axle shafts 36a, 36b.

Referring to FIG. 4, the input gearbox 50 preferably includes a planetary gear assembly 51. The electric motor shaft 38 drives a sun gear 52 that drives a multiple of planet gears 54 that revolve within an outer gear 56 preferably formed within an input gearbox housing 58. The planet gears 54 drive a planet carrier 60, which is mounted to the pinion gear 44 through splines 62 or the like. The planet carrier 60 supports the planet gears 54 on pins 64 which define an axis of rotation for each of the planet gears 54 that is parallel to and displaced from axis E. The planetary gear assembly 51 reduces the speed from the motor shaft 38 to the pinion gear 44.

The input yoke 34 drives an input shaft 66 that is directly engaged with the planet carrier 60 through the pins 64. That is, as the planet carrier 60 is mounted to the pinion gear 44 through the pins 64, the input shaft 66 directly drives the pinion gear 44 without speed reduction. Preferably, the input shaft 66 is supported by a bearing 68 between the input shaft 66 and the input gearbox housing 58.

Referring to FIG. 5, another axle assembly 20 may alternatively be powered by just the single electric motor 24 to provide a relatively lighter duty axle assembly 20 for yet another vehicle configuration without major modification to the axle assembly 20. The axle assembly 20 is driven by the electric motor 24 such that the input shaft 66 does not require an input yoke. A cover 70 protects an end of shaft 66. It should be understood that various combinations of the axle assemblies described herein may be provided to particularly tailor an axle assembly to a particular vehicle in a modular manner.

The inclusion of an electric motor 24 directly to the axle assembly 20 utilizes relatively conventional axle, driveline, and suspension components to minimize redesign of the vehicle structure to provide a more efficient intercity transport and the like with hybrid power. That is, the electric motor 24 is mounted to the electric motor housing portion 30 to provide the advantages of utilizing an electric power system without significantly effecting how the axle assembly 20 is alternatively or additionally driven by conventional motive forces such as an internal combustion engine.

The foregoing description is exemplary rather than defined by the limitations within. Many modifications and variations of the present invention are possible in light of the above teachings. The preferred embodiments of this invention have been disclosed, however, one of ordinary skill in the art would recognize that certain modifications would come within the scope of this invention. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. For that reason the following claims should be studied to determine the true scope and content of this invention.

What is claimed is:

1. An axle assembly comprising:
   a first hub assembly and a second hub assembly mounted to an axle housing for rotation about a first axis through a reduction gearbox within said axle housing, said axle housing having an electric motor axle housing portion located intermediate said first hub assembly and said second hub assembly, said electric motor axle housing portion configured to receive an electric motor along a second axis transverse said first axis to drive said reduction gearbox opposite an input yoke which drives said reduction gearbox.

2. The axle assembly as recited in claim 1, further comprising an electric motor mounted along said second axis, said electric motor mounted to said electric motor axle housing portion on one side of said first axis.

3. The axle assembly as recited in claim 2, wherein said input yoke is disposed along said second axis opposite said electric motor.

4. The axle assembly as recited in claim 3, further comprising a motor shaft mounted for rotation about said second axis and driven by said electric motor, said motor shaft offset from said first axis.

5. The axle assembly as recited in claim 4, further comprising a planetary gear assembly comprising a sun gear driven by said motor shaft, said planetary gear assembly located within an input gearbox housing portion adjacent said electric motor axle housing portion and said input yoke.

6. The axle assembly as recited in claim 5, wherein said planetary gear assembly drives a pinion gear, said motor shaft extending through said pinion gear.

7. The axle assembly as recited in claim 6, wherein said input yoke drives said pinion gear through a planet carrier of said planetary gear assembly.

8. The axle assembly as recited in claim 6, further comprising a ring gear engaged with said pinion gear, said ring gear engaged with said reduction gearbox to drive said first and second hub assemblies.

9. The axle assembly as recited in claim 8, wherein said ring gear is coaxial with said first axis.

10. The axle assembly as recited in claim 1, wherein said electric motor axle housing portion includes a semi-spherical portion.

11. The axle assembly as recited in claim 1, further comprising said electric motor having a motor shaft mounted through a pinion gear of said reduction gearbox mounted for rotation with said input yoke.

12. The axle assembly as recited in claim 11, wherein said pinion gear is mounted to said input yoke for one-to-one rotation.

13. The axle assembly as recited in claim 1, further comprising said electric motor having a motor shaft mounted through a pinion gear of said reduction gearbox mounted to said input yoke, said motor shaft engaged with a gear reduction to drive said pinion gear therethrough.

14. The axle assembly as recited in claim 13, wherein said pinion gear is mounted to said input yoke through a set of planet carrier pins such that said input yoke drives said pinion gear without speed reduction.

15. An axle assembly comprising:
   an axle housing;
a first hub assembly and a second hub assembly mounted to said axle housing for rotation about a first axis; said axle housing having an electric motor axle housing portion intermediate said first hub assembly and said second hub assembly; a gearbox mounted within said electric motor axle housing portion, said gearbox operable to drive said first hub assembly and said second hub assembly; a motor shaft mounted within said electric motor axle housing portion and rotatable along a second axis transverse said first axis, said motor shaft engaged with said gearbox; and an input yoke disposed along said second axis, said input yoke engaged with said gearbox, said input yoke opposite said motor shaft.

16. The axle assembly as recited in claim 15, further comprising an electric motor providing a drive input along said second axis to drive said motor shaft.

17. An axle assembly comprising:

an axle housing;
a first hub assembly and a second hub assembly mounted to said axle housing for rotation about a first axis;
said axle housing having an electric motor axle housing portion intermediate said first hub assembly and said second hub assembly;
a gearbox mounted within said electric motor axle housing portion, said gearbox operable to drive said first hub assembly and said second hub assembly;
a motor shaft mounted within said electric motor axle housing portion and rotatable along a second axis transverse said first axis, said motor shaft engaged with said gearbox;
an input yoke disposed along said second axis, said input yoke engaged with said gearbox, an electric motor providing a drive input along said second axis to drive said motor shaft; and a selectively actuated coupling between said electric motor and said motor shaft.

18. The axle assembly as recited in claim 15, further comprising a planetary gear assembly engaged with said gearbox, said motor shaft, and said input yoke.

19. An axle assembly comprising:

an axle housing;
a first hub assembly and a second hub assembly mounted to said axle housing for rotation about a first axis;
said axle housing having an electric motor axle housing portion intermediate said first hub assembly and said second hub assembly;
a gearbox mounted within said electric motor axle housing portion, said gearbox comprises a ring gear engaged with a pinion gear operable to drive said first hub assembly and said second hub assembly;
a motor shaft mounted within said electric motor axle housing portion to extend through said pinion gear, said motor shaft rotatable along a second axis transverse said first axis; and an input yoke disposed along said second axis, said input yoke engaged with said gearbox.

20. The axle assembly as recited in claim 19, further comprising a planetary gear assembly engaged with said pinion gear, said motor shaft engageable with said planetary gear assembly at a first speed ratio and said input yoke engageable with said planetary gear assembly at a second speed ratio.

21. The axle assembly as recited in claim 20, including a planet carrier in driving engagement with said pinion gear wherein said input yoke is engaged with said planet carrier to directly drive said planet carrier.

22. The axle assembly as recited in claim 20, wherein said planetary gear assembly comprises a sun gear driven directly by said motor shaft.

23. The axle assembly as recited in claim 15, where said first axis is perpendicular to said second axis.

24. An axle assembly comprising:

an axle housing;
a first hub assembly and a second hub assembly mounted to said axle housing for rotation about a first axis;
said axle housing having an electric motor axle housing portion intermediate said first hub assembly and said second hub assembly;
an electric motor mounted to said electric motor axle housing portion, said electric motor providing a drive input along a second axis transverse to said first axis; a gearbox mounted within said electric motor axle housing portion to drive said first hub assembly and said second hub assembly;
a planetary gear assembly engaged with said gearbox; an input yoke being rotatable about said second axis and engaged with said planetary gear assembly, such that said input yoke directly drives a planet carrier of said planetary gear assembly; and a motor shaft rotatable about said second axis, said motor shaft engaged with said electric motor to drive said planetary gear assembly said electric motor mounted on an opposite side of said first axis relative to said input yoke.

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